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Assessment of soil nutrients of Thimmapura sub-watershed for enhancing crop productivity using remote sensing and GIS

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Abstract
Soil samples from Thimmapura sub-watershed in northern dry zone of Karnataka were drawn at 250 m grid interval and assessed for their fertility parameters. Analytical data was interpreted and statistical parameters like range, mean standard deviation, coefficient of variation, kurtosis and skewness were calculated for each parameter. Soil fertility maps were prepared for each parameter under GIS environment using Arc GIS v 10.4. Soils were slightly alkaline to strongly alkaline with non saline to slight salinity. Majority of area in micro-watershed is low to high in Soil organic carbon content and low to medium in available phosphorous and available boron, available nitrogen was low in majority of area, available potassium was medium to high and sulphur was medium. Regarding available micronutrients, zinc and iron were deficient in more than half of the sub watershed area, whereas copper and manganese were sufficient in the soils and boron was low to medium. The mapping of nutrients by GIS technique in the sub watershed revealed that, available N, P, S, Zn,B and Fe are important soil fertility constraints.

Keywords: Soil fertility map, Watersheds, Soil fertility constraints, Nutrients

Introduction
Soil is the vital natural resource for the survival of life on the earth and its assessment is the prerequisite for the determination of productivity of soil and the sustainability of the ecosystem. Therefore, assessment of nutrient constraints of soils being intensively cultivated with high yielding crops need to be carried out. Soil testing is usually followed by collecting composite soil samples in the fields without geographic reference. The results of such soil testing are not useful for site specific recommendations and subsequent monitoring. Soil available nutrient constraints of an area using global positioning system (GPS) will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally. Geographic information system (GIS) is a powerful tool which helps to integrate many types of spatial information such as agro-climatic zone, land use, soil management, etc. to derive useful information. Watershed is a holistic approach emerged for rainfed areas, which can lead to higher productivity and sustainability by conservation of soil and water resources simultaneously.

Intensively cultivated soils are being depleted with available nutrients especially micronutrients. Therefore, assessment of nutrient constraints of soils that are being intensively cultivated with high yielding crops needs to be carried out. Soil testing is usually followed by collecting composite soil samples in the fields without geographic reference. The results of such soil testing are not useful for site specific recommendations and subsequent monitoring. Soil available nutrients constraints of an area using Global Positioning System (GPS) will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally. Geographic information system (GIS) is a powerful tool which helps to integrate many types of spatial information such as agro-climatic zone, land use, soil management, *etc*. to derive useful information (Adornado and Yoshida 2008) [1]. It has been documented very well that dry land soils are not only thirsty but hungry too (Wani 2008) [19] meaning that besides soil and water conservation, if nutrient management issues are addressed, the productivity of a watershed is further enhanced. Some studies on soil fertility status at representative micro–watershed/village level have been carried out at University of Agricultural Sciences, Dharwad for a few agro ecological zones. Such information is not available for contiguous micro watersheds or for a sub watershed in Karnataka and is essential in planning soil fertility management on a sub watershed area basis. The proposed study was planned with the objective of identifying available nutrients constraints in soils of Thimmapura sub watershed in northern dry zone of Karnataka.

Materials and Methods

The Thimmapura Sub-watershed is located in Gadag taluka of Gadag district covering an area of 4811 ha (Fig 1.0), falling under Northern Dry Zone of Agro climatic Zones of Karnataka. The sub-watershed consists of eleven micro watersheds having undulating topography with a forest area. The peninsular gneiss covers the sub-watershed area. The predominant minerals observed in the peninsular gneiss are oligoclase and orthoclase feldspar. The climate of the area is hot dry subhumid and monsoonic type. The maximum temperature during summer is 42.7°C and the minimum 16.1°C in winter. Mean maximum temperature was 36.56^{0}C and mean minimum temperature was 20.43^{0}C (Table 2). The average annual rainfall is 464.5 to 785.7 mm. It is well distributed with southwest monsoon (June to September).

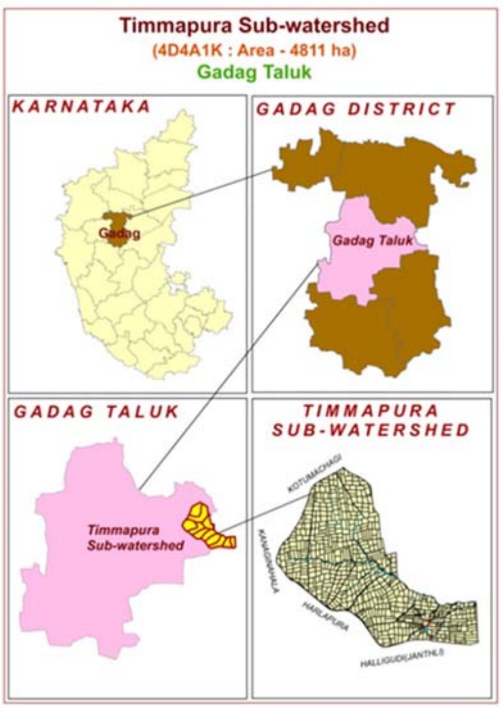

Fig. 1: Location map of Thimmapura sub watershed

Surface composite soil samples were collected during April 2016 on grid points of 250 m interval in the study area and the sample location was recorded by GPS. A total of 769 samples were collected from the sub watershed. Micro watershed wise soil sample details are furnished in table 1.

Table 1: Details of soil sampling in Thimmapura sub watershed

Micro watershed	Code	Area(ha)	No. of Samples
Thimmapur 1	4D4A1K2c	423.57	38
Thimmapur 2	4D4A1K2b	477.40	43
Thimmapur 3	4D4A1K2a	409.42	51
Thimmapur 4	4D4A1K2d	278.35	47
Thimmapur 5	4D4A1K2e	203.17	45
Thimmapur 6	4D4A1K1f	419.14	62
Thimmapur North 1	4D4A1K1c	526.95	97
Thimmapur North 2	4D4A1K1a	530.07	103
Thimmapur North 3	4D4A1K1d	415.09	94
Thimmapur North 4	4D4A1K1b	743.75	91
Thimmapur North 5	4D4A1K1e	384.52	98
Total		4811	769

The soil samples were air-dried, ground (< 2 mm) and analyzed for chemical and fertility parameters. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Jackson (1973). Organic carbon (OC) was determined using the Walkley-Black method (Nelson and Sommers 1996) [4]. Available nitrogen (N) was estimated by modified alkaline permanganate method (Sahrawat and Burford, 1982) [13]. Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen and Sommers 1982) [5]. Available potassium (K) was determined using the ammonium acetate method (Helmke and Sparks 1996) [2]. Available sulphur (S) was measured using 0.15% calcium chloride ($CaCl_2$) as an extractant (Tabatabai 1996) [18]. Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA reagent using the procedure outlined by Lindsay and Norvell (1978) [3]. Variability of data was assessed using mean standard deviation and coefficient of variation for each set of data. Availability of N, P, K and S in soils are interpreted as low, medium and high and that of available zinc, iron, copper and manganese interpreted as deficient and sufficient by following the criteria given in table 2.

A *dbf* file consisting of data for X and Y co-ordinates in respect of sampling site location was created. A shape file (Vector data) showing the outline of Thimmapura sub watershed area was created in *Arc GIS 10.4*. The *dbf* file was opened in the project window and in X-field, ``longitudes`` and in Y-field, ``latitudes`` were selected. The Z field was used for different nutrients. The Thimmapura sub watershed file was also opened and from the ``Surface menu`` of Arc GIS geo-statistical Analyst, “geo statistical wizard`` option was selected. On the output “grid specification dialogue”, output grid extend chosen was same as Thimmapura sub watershed and the interpolation method employed was krigging. Then map was re classified based on ratings of the respective nutrients (Table 2) and area for each category of nutrient was calculated.

Table 2: Soil fertility ratings for available nutrients

Nutrients	**Fertility rating major nutrients**		
	Low	**Medium**	**High**
Organic carbon (g kg^{-1})	<5	5-7.5	>7.5
Macronutrients (kg ha^{-1})			
Nitrogen (N)	<280	280-560	>560
Phosphorus(P_2O_5)	<22.5	22.5-55	>55
Potassium (K_2O)	<140	140-330	>330
Sulphur (S) (mg kg^{-1})	<10	10-20	>20
Micronutrients (mg kg^{-1})	**Deficient**	**Sufficient**	**Excess**
Zinc (Zn)	<0.6	0.6-1.5	>1.5
Iron (Fe)	<2.5	2.5-4.5	>4.5
Copper (Cu)	<0.2	0.2-5.0	>5.0
Manganese (Mn)	<2.0	2-4	>4.0

Results and Discussion

Soil reaction and electrical conductivity

Soils of the Thimmapura sub-watershed were slightly alkaline to very strongly alkaline in reaction (6.68 to 9.34) with a mean pH of 8.42, standard deviation of 0.53 and coefficient of variation of 6.28 (Table 3). Higher soil reaction in the sub watershed is mainly because of calcareousness nature and sodicity of the soils. The coefficient of variation of soil pH indicates that, spatially it did not vary. Mapping of soil pH by GIS technique resulted in five soil reaction classes (Fig. 2). They are; Neutral (6.5 – 7.3), Slightly alkaline (7.3 – 7.8), Moderately alkaline (7.8 – 8.4), Strongly alkaline (8.4 – 9.0), Very strongly alkaline (> 9.0). Major proportion of the sub watershed area (Fig 2) was strongly alkaline (57.37%) followed by moderately alkaline (34.92%), slightly alkaline (5.04%) and very strongly alkaline (0.91%). The higher pH of soils could be attributed to low intensity of leaching and accumulation of bases. (Ravikumar *et al.*, 2007a, and Prabhavati *et. al* 201) [11, 9]. The EC of soils in the sub-watershed was in the range of 0.08 to 2.52 dSm^{-1} with mean value of 0.29 dSm^{-1} and standard deviation of 0.25. The CV (87.81) of EC values indicate that salt content in the sub watershed varied spatially. Higher level of soluble salts in the study area is due to arid climatic condition. GIS Mapping of soluble salt content in the sub watershed (Fig 3) revealed that, 90.64 per cent of the area was non saline whereas and 7.61 per cent of the area was slightly saline.

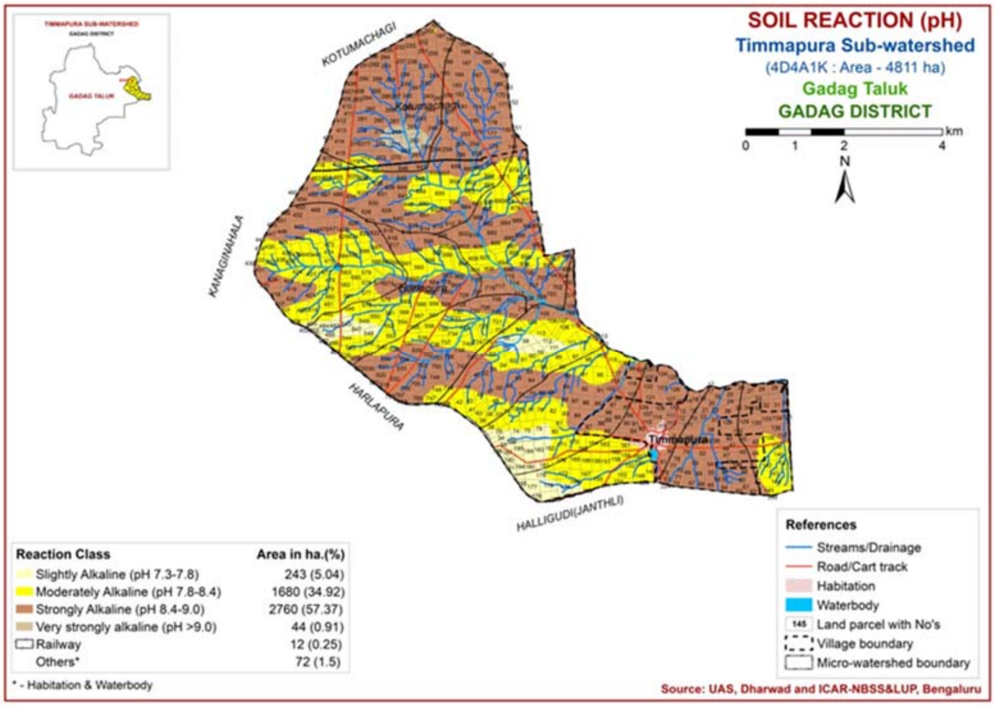

Fig. 2: Soil Reaction status of Thimmapura Sub watershed

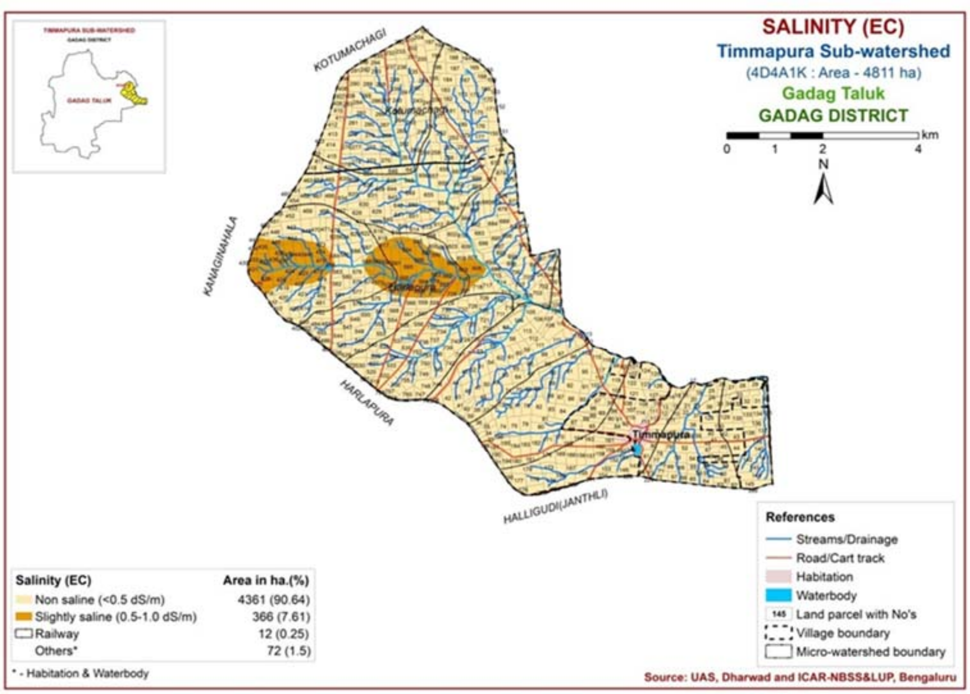

Fig. 3: Salinity status of Thimmapura Sub watershed

Organic carbon

Organic carbon content of soils of Thimmapura sub watershed was ranged from 0.08 to 1.09 gkg^{-1} with mean and standard deviation value of 0.48 and 0.19 gkg^{-1} respectively. The CV (39.83) for OC content indicates that, in the sub watershed SOC varied spatially (Table 3). GIS Mapping of OC by GIS revealed that 62.12per cent of the study area was low in organic carbon, 34.44 per cent area was medium and 1.68 per cent area was high in soil organic carbon status (Fig 4). The values obtained in the present study are in agreement with those reported by for, Ravikumar *et al.*, (2007a) [11] and Patil *et al.*, (2011) [8] for black soils of Malaprabha command area of Karnataka. The reason for low organic carbon content in these soils may be attributed to the prevalence of arid condition, where the degradation of organic matter occur at a faster rate coupled with little or no addition of organic manures and low vegetative cover on the fields, thereby leaving less chances of accumulation of organic carbon in the soils. Intensive cropping is also one of the reasons for low organic carbon content. The similar results were also reported by Prabhavati *et. al* (2015) [9] for the soils of northern dry zone of Karnataka.

Table 3: Chemical properties and available major nutrients status in Thimmapura sub watershed

	pH	EC	OC	N	P_2O_5	K_2O	S
		dSm^{-1}	gkg^{-1}	$Kgha^{-1}$			$mgkg^{-1}$
Average	8.42	0.29	0.48	150.26	29.20	597.15	14.52
SD	0.53	0.25	0.19	27.31	9.86	177.74	2.67
Range	6.68-9.34	0.08-2.52	0.08-1.09	110-267	20.0-68.1	52-1010	10.0-33.8
CV	6.28	87.81	39.83	18.17	33.76	29.76	18.39

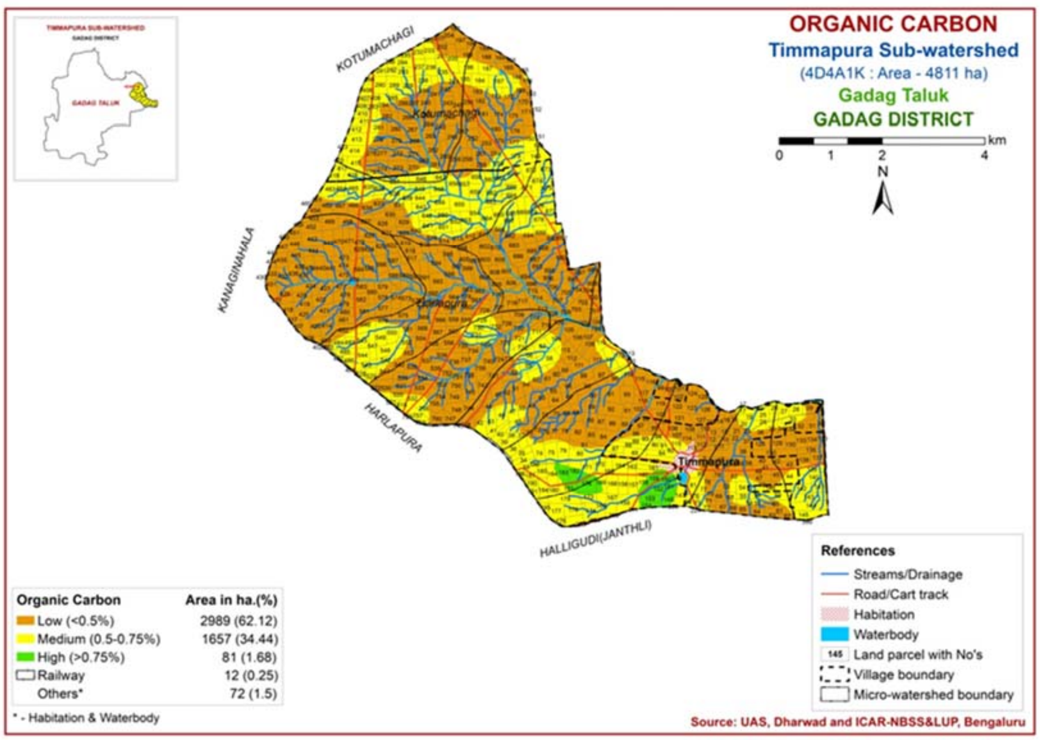

Fig. 4: Soil Organic Carbon status of Thimmapura Sub watershed

Available macronutrients

The available N in soils of the sub watershed ranged from 110 to 267 kg ha^{-1} with a mean of 150 kg ha^{-1} and SD of 27.31. The CV value of 18.17 indicates that available N in soils varied spatially. GIS mapping revealed that, the entire sub watershed was low in the available nitrogen (Table 3 and Fig 5). The low N content could be attributed to soil management, varied application of FYM and fertilizer to previous crops. Nitrogen is the most limiting nutrient in black soils as its availability decreases due to fixation and volatilization losses. Another possible reason may also be due to low organic matter content in these areas due to low rainfall and high temperature which facilitate faster degradation and removal of organic matter leading to nitrogen deficiency. Similar nitrogen status was reported by Pulakeshi *et al*, (2012) [10] in non-saline clay to sandy loams and calcareous soils.

The available P_2O_5 content of the sub watershed was ranged from 20.0 to 68.1 kg ha^{-1} with average and SD value of 29.2 and 9.86 kg ha^{-1} respectively. The CV (33.76) for available P_2O_5 distribution in the sub watershed indicates that, it was varied spatially. Mapping of available P_2O_5 by GIS revealed that, available P_2O_5 was low in 1.14 per cent of the study area whereas, it was medium in 97.11 per cent of the study area (Table 3 and Fig 6). Low P_2O_5 availability in these soils is related to their high pH, calcareousness and low organic matter content. Ravikumar *et al.*, (2007a) [11] and Patil *et al.*, (2011) [8] reported for black soils of Malaprabha command area of Karnataka that available P_2O_5 status in the soils was low due to high calcium carbonate content. The present findings are in line with those of Shiva Prasad *et al.* (1998) [15] who reported that majority of the soils in Karnataka were medium in phosphorus content.

The available K_2O content in the sub watershed was ranged from 52 to 1010 kg ha^{-1} with mean and SD value of 597 and 177.74 kg ha^{-1} respectively. The CV (29.76) for available K_2O content indicates that, it varied spatially in the sub watershed. Mapping of available K_2O content in the sub watershed by GIS revealed that, 0.84 per cent of the of the study area was in medium category (Table 3 and Fig 7), 97.41 per cent of the of the study area was in high category. It is reported that, invariably the surface soils had higher concentration of water soluble and exchangeable K in Karnataka (Patil *et al*., 2011) [8]. Soils are able to maintain a sufficient or even high level of exchangeable K and provide a good supply of K to plants for many years. The higher content of available potassium in soils of Thimmapura sub watershed may be due to the predominance of potash rich micaceous and feldspar minerals in parent material. Similar results were observed by Srikant *et al*., (2008) [17].

The available sulphur content of soils of the sub watershed varied from 10.0 to 33.8 mg kg^{-1} soil with mean and SD values of 14.5 and 2.67 mg kg^{-1} soil respectively. The CV (18.39) for available S content indicates that, in the sub watershed available S varied spatially. GIS mapping of available S revealed that, the entire area under study was medium in available sulphur status (Table 3 and Fig 8). Low and medium level variation of available sulphur was due to lack of sulphur addition and continuous removal of S by crops (Shankaraiah *et. al.* 2006) [14].

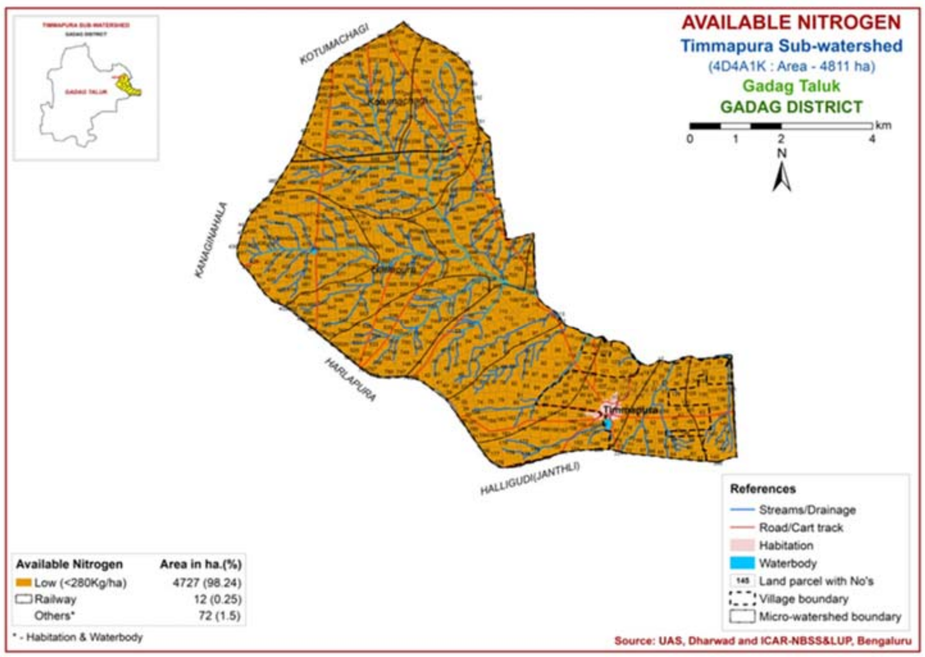

Fig. 5: Available Nitrogen status of Thimmapura Sub watershed

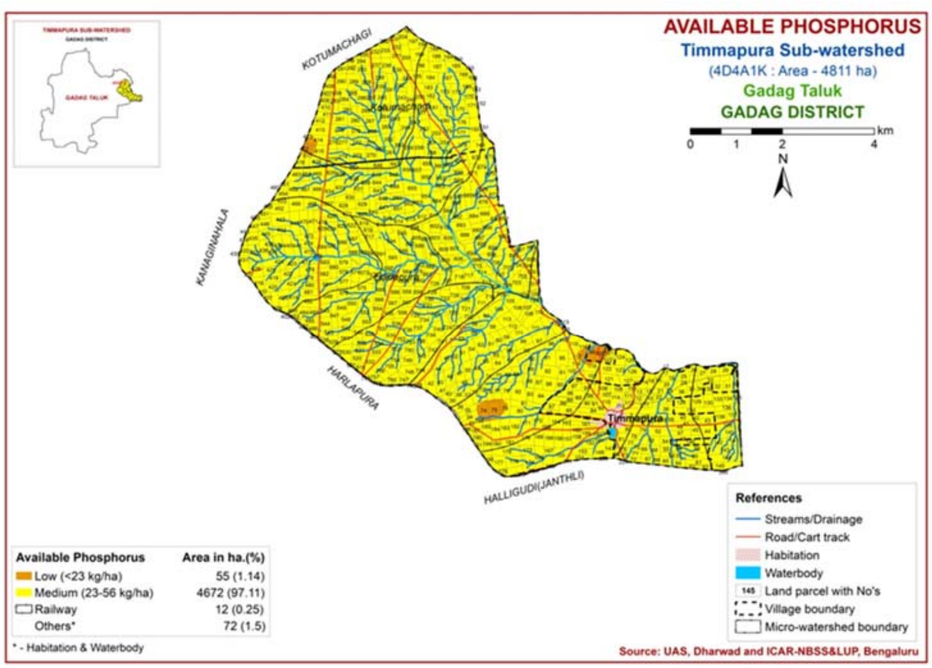

Fig. 6: Available Phosphorus status of Thimmapura Sub watershed

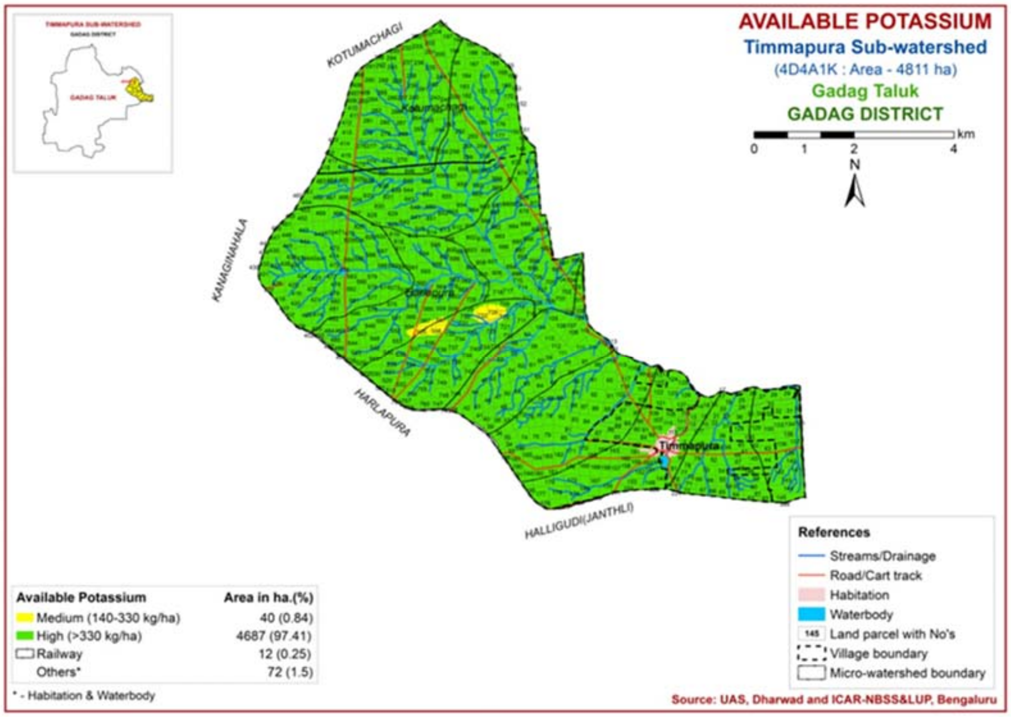

Fig. 7: Available Potassium status of Thimmapura Sub watershed

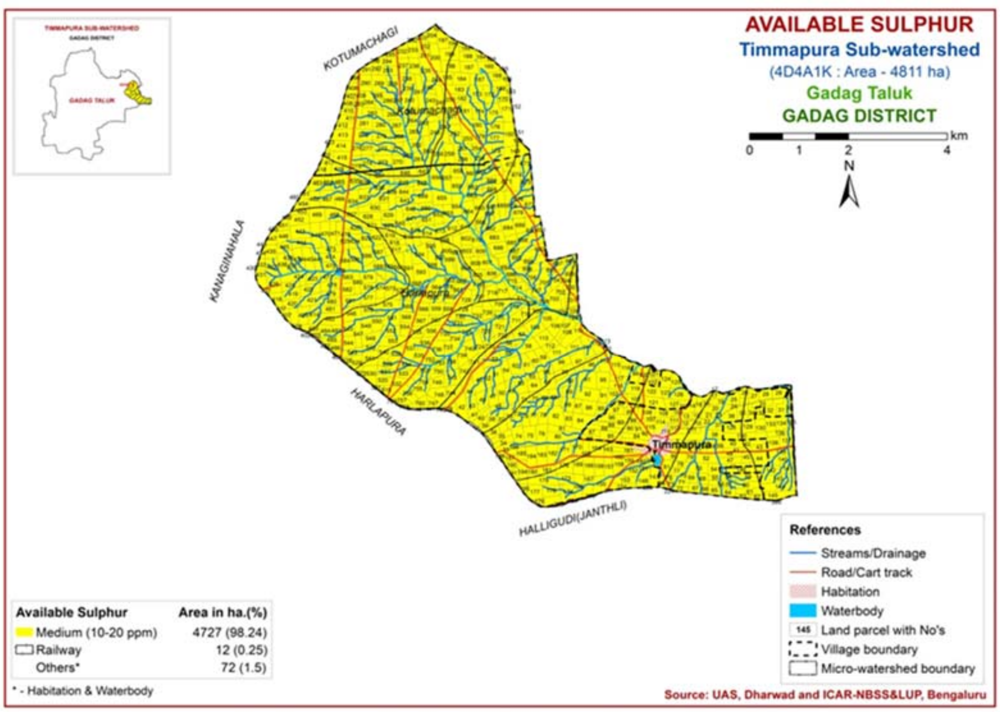

Fig. 8: Available Sulphur status of Thimmapura Sub watershed

Available micro nutrients

The available zinc in the sub watershed was ranged from 0.14 to 3.52 mg kg^{-1} with mean and SD value of 0.42 and 0.28 mg kg^{-1} respectively (Table 4). The CV (65.18) for available Zn content indicates that, it varied spatially in the sub watershed. Mapping of available Zn by GIS revealed that, it was deficient in the 88.7 per cent of the study area and sufficient in 9.54 per cent of the area (Fig 9). The content of Zn increases with low pH and high organic carbon content but decreases with increase in pH. Since, the most of the soils are alkaline, low in OC and dominated by $CaCO_3$, zinc may be precipitated as hydroxides and carbonates as a result, their solubility and mobility might have decreased and reduced the availability. Similar results were reported by Ravikumar *et al.,* (2007b) [12], Patil *et al*., (2006) [7] and Pulakeshi *et al*, (2012) [10].

Table 4: Available micro nutrients status in Thimmapura sub watershed

	Zn	Fe	Mn	Cu
	mg kg^{-1}			
Average	0.42	3.87	3.73	1.18
SD	0.28	0.84	0.94	0.50
Range	0.14-3.59	1.05-6.20	2.00-7.92	0.22-3.39
CV	65.18	21.63	25.10	42.60

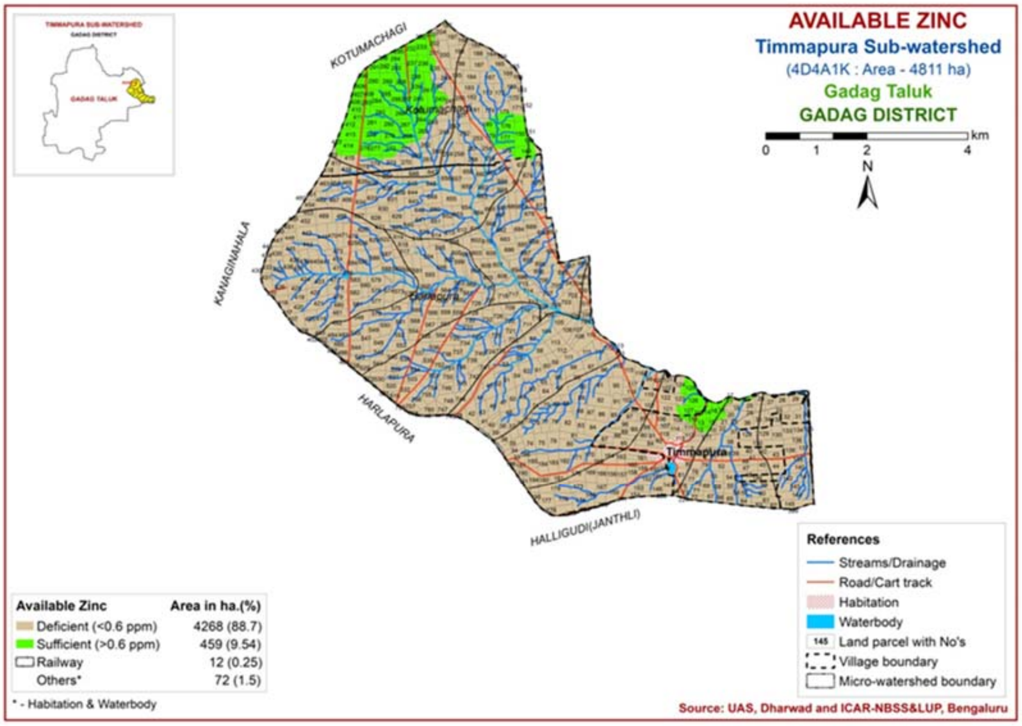

Fig. 9: Available Zinc status of Thimmapura Sub watershed

The available iron in the sub watershed was ranged from 1.05 to 6.20 mg kg^{-1} with mean and SD value of 3.87 and 0.84 mg kg^{-1} respectively (Table 4). The CV (21.63) for available Fe content indicates that, it varied spatially in the sub watershed. Mapping of available Fe by GIS revealed that, it was deficient in the 92.24 per cent of the study area and sufficient in 6.0 per cent of the area (Fig 10). The low Fe content may be due to precipitation of Fe by $CaCO_3$ and decreased its availability. Similar results were also observed by Ravikumar *et al.*, (2007b) [12] and Patil *et al*., (2006) [7]. The available iron in surface soils has no regular pattern of distribution as also reported by Nayak *et al.* (2002). This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

The available Manganese in the sub watershed was ranged from 2.00 to 7.92 mg kg^{-1} with mean and SD value of 3.73 and 0.94 mg kg^{-1} respectively (Table 4). The CV (25.10) for available Mn content indicates that, it varied spatially in the sub watershed. Mapping of available Mn by GIS revealed that, it was sufficient in the entire study area. Sufficient content of manganese was observed by Ravikumar *et al*. (2007b) [12] in Vertisols of Malaprabha command area, Pulakeshi *et al.* (2012) [10] in the soils of northern transition zone of Karnataka derived from chlorite schist and Manojkumar (2011) [6] in the soils of northern transition zone of Karnataka derived from basalt.

The available copper in the entire sub watershed was sufficient and ranged from 0.22 to 3.39 mg kg^{-1} with mean and SD value of 1.18 and 0.50 mg kg^{-1} respectively (Table 4). The CV (42.60) for available Cu content indicates that, it varied spatially in the sub watershed. Mapping of available Cu by GIS revealed that, it was sufficient in the entire study area. Ravikumar *et al*. (2007b) [12], Pulakeshi *et al.* (2012) [10] and Manojkumar (2011) [6] also observed sufficient status of available copper in soils of North Karnataka.

The available boron in the sub watershed was low to medium and ranged from 0.10 to 0.98 mg kg^{-1} with mean and SD value of 0.28 and 0.17 mg kg^{-1} respectively (Table 4). The CV (59.36) for available boron content indicates that, it varied spatially in the sub watershed. Mapping of available boron by GIS revealed that, 90.31 per cent area is low and 7.93 per cent area is medium in the entire study area.

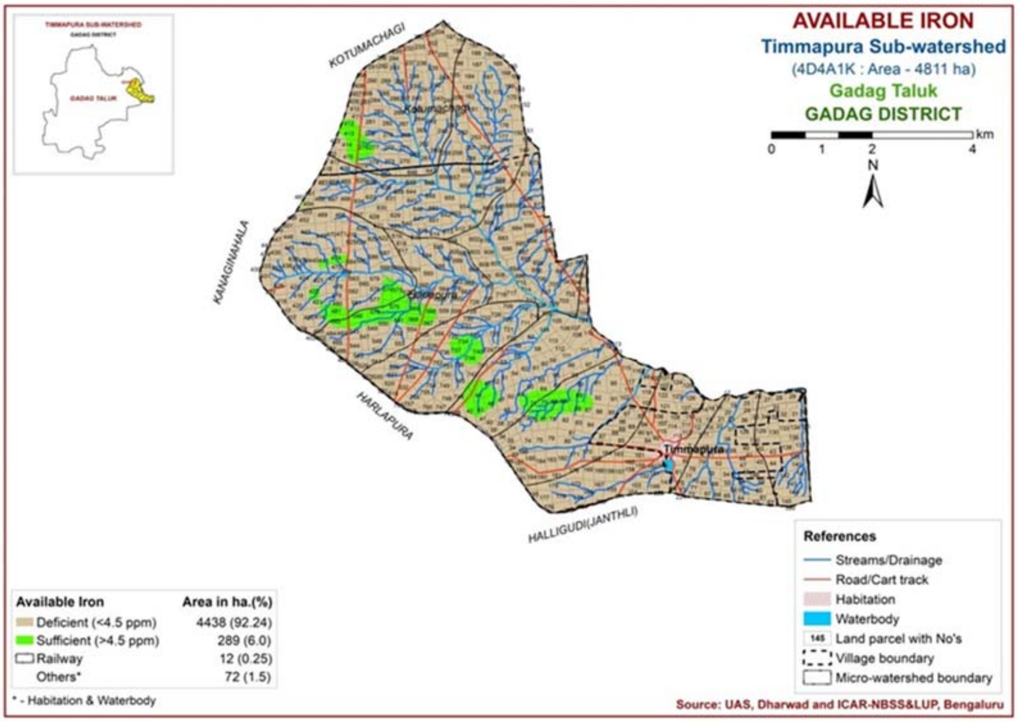

Fig. 10: Available Iron status of Thimmapura Sub watershed

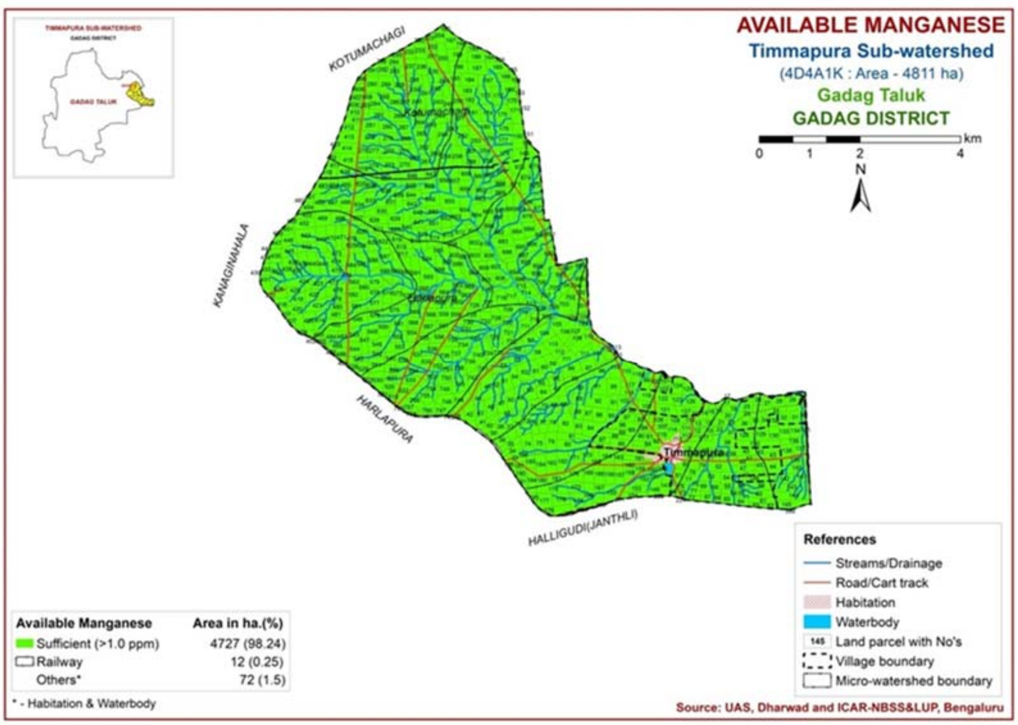

Fig. 11: Available Manganese status of Thimmapura Sub watershed

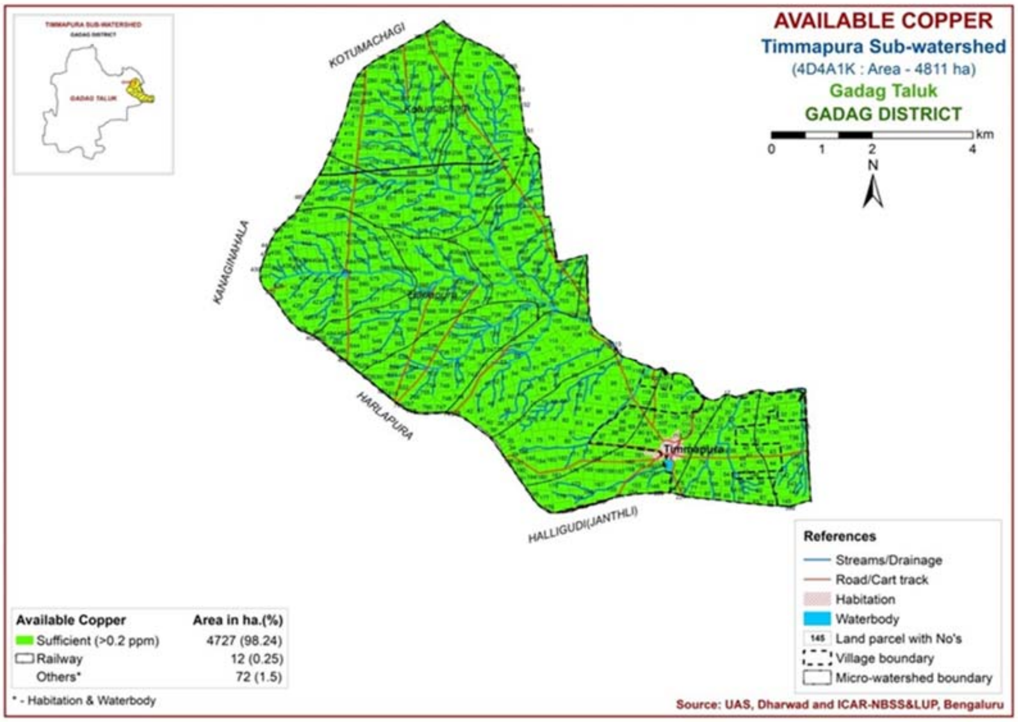

Fig. 12: Available Copper status of Thimmapura Sub watershed

Conclusion

From the study, it can be concluded that, soils of Thimmapura sub-watershed in northern dry zone of Karnataka are slightly alkaline to very strongly alkaline with non saline to slight salinity. Alkaline soils in the study area need immediate attention for their management to arrest further degradation. Soil organic carbon content and available phosphorous was low to medium. Available nitrogen was low, available potassium was medium to high and sulphur was medium. Regarding available micronutrients, zinc and iron were deficient in about more than half of the sub watershed area whereas, copper and manganese were sufficient in the soils, boron was low in more than half of the sub-watershed area. The mapping of nutrients by GIS technique in the sub watershed revealed that major portion of the study area was deficient in available N, P, S, Zn, B and Fe are important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient micronutrient may be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

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